A Survey on the History of Relations between BAM and Sandia NL

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BAM/Sandia Workshop
Albuquerque, NM, USA, October 6-8, 2014

BAM/Sandia Cooperation after meetings at PATRAM 1978, Las Vegas

High speed impact testing of a modified
18/8 Container for Pu-nitrate
Sandia test site May 15, 1979

SAND79-1404C
TTC/0019

EXTENDED TESTING OF AN APPROVED SHIPPING CONTAINER FOR PLUTONIUM COMPOUNDS

H. R. Yoshimura
R. B. Pope
Sandia Laboratories, Albuquerque, New Mexico

H. W. Huebner
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Bundesanstalt fuer Materialpruefung
Berlin, Federal Republic of Germany

For the past several years, considerable effort has been made to enhance the safety of transporting plutonium compounds by air. This is illustrated by the promulgation of a special set of criteria for the air transport of Plutonium (Reference 1) and by the development of a Plutonium Air Transportable (PAT) package which satisfies these criteria (Reference 2) in the United States. The IAEA regulations (Safety Series No. 6) specify a series of sequential tests simulating hypothetical accident conditions (impact, puncture, fire and immersion) that packagings must survive without loss of contents before these packagings can be certified for shipment. These regulations are currently mode independent. Based on IAEA Safety Series No. 6 criteria, a low cost shipping container for the transport of 10 liters of plutonium nitrate solution was designed, constructed, tested and approved under Federal Republic of Germany (FRG) D/DB-0018B. About forty of these packagings are in use for highway/rail transport by the FRG. Due to the mode independent nature of Safety Series No. 6, this licensed package could be carried by air.

It has been found in risk assessment studies performed by Sandia and Battelle Pacific Northwest Laboratories that some accident environments may be encountered during air transport which exceed those specified in the current regulations. NUREG-0360 (Reference 1) required extended testing far beyond that specified in IAEA Safety Series No. 6. In an effort to further understand the effects of super-regulatory environments on packagings, additional tests in the form of extended fire testing, extended drop testing followed by fire, dynamic crush, and high velocity impact were performed by Bundesanstalt fuer Materialpruefung (BAM) and by Sandia Laboratories (SLA).

This paper reviews the results of the regulatory and extended testing of a modified I8B plutonium shipping container. The overpack is fabricated with two concentric steel tubes with axial and radial spacers. The intervening tube layers are filled with phenolic foam insulation, which provides both thermal and impact resistance. The T-shaped lid is of foamed construction and is designed to swage into the upper part of the inner tube assembly when stressed by a severe mechanical impact, thus providing an additional containment barrier.

The titanium containment vessel, which is carried within the overpack, was designed and tested as a pressure vessel (test pressure = 30 bar) with helium leaktightness of the order of 10^{-8} mbar s/liter. The approved

*This work was supported in part by the US Department of Energy and the FRG Bundesanstalt fuer Materialpruefung.

SANDIA NATIONAL LABORATORIES (SNL)

BUNDESANSTALT FÜR MATERIALFORSCHUNG UND -PRÜFUNG (BAM)

BILATERAL ARRANGEMENT ON COOPERATION AND TECHNICAL EXCHANGE BETWEEN THE UNITED STATES OF AMERICA (U.S.A.) AND THE FEDERAL REPUBLIC OF GERMANY (FRG) ON RESEARCH RELATED TO RADIOACTIVE MATERIAL TRANSPORTATION

SUMMARIZING FINAL REPORT

K. B. Sorenson (SNL)

B. Günther (BAM)

The project was financed by:

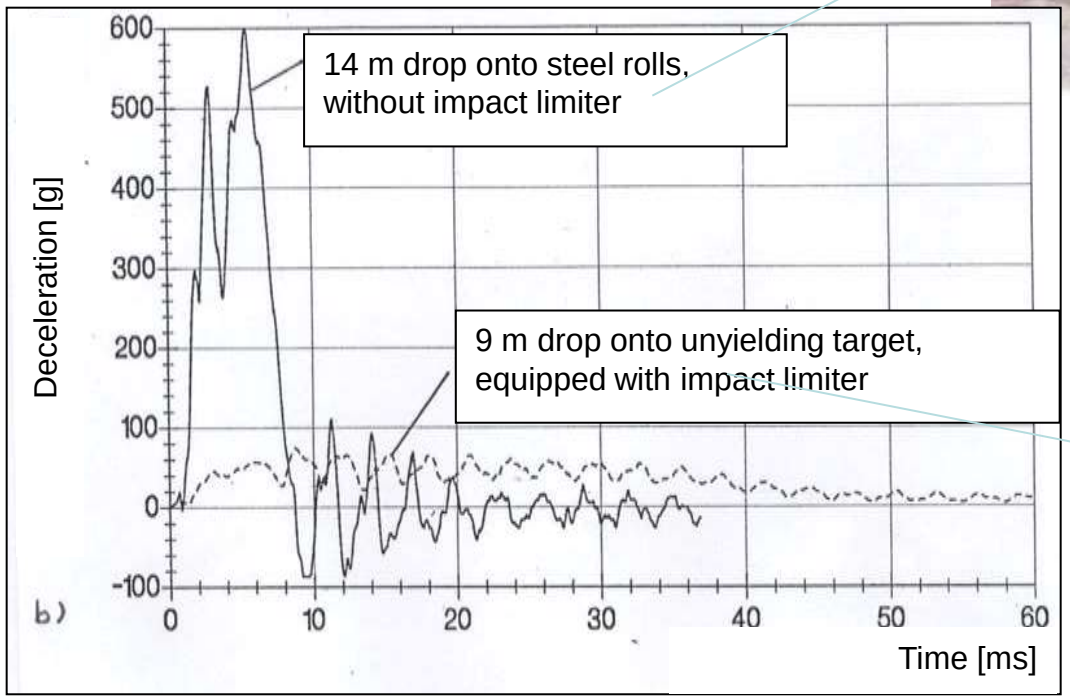
Department of Energy (DOE) for the U.S.A.

Bundesministerium für Forschung und Technologie (BMFT) for the FRG. Project Number: 315/316-5691-KWA 3502/5

Joint BAM/Sandia Drop Test Program

14m drop test with the CASTOR VHLW cask (with a 120 mm deep failure inside the 260 mm ductile iron wall) in comparison with the regulatory 9-m drop test

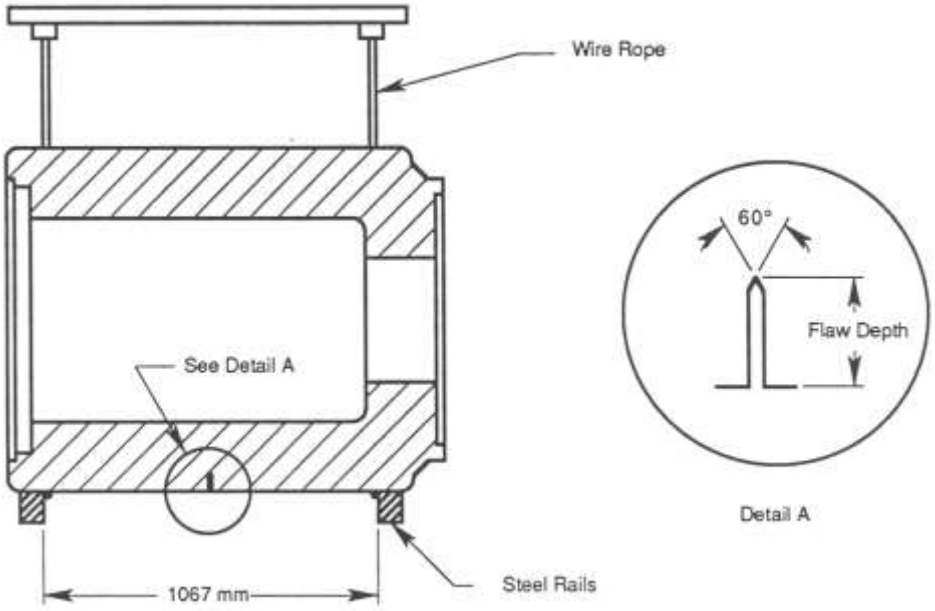
Regulatory tests for US approval accompanied by Sandia measurements at BAM test site Lehre



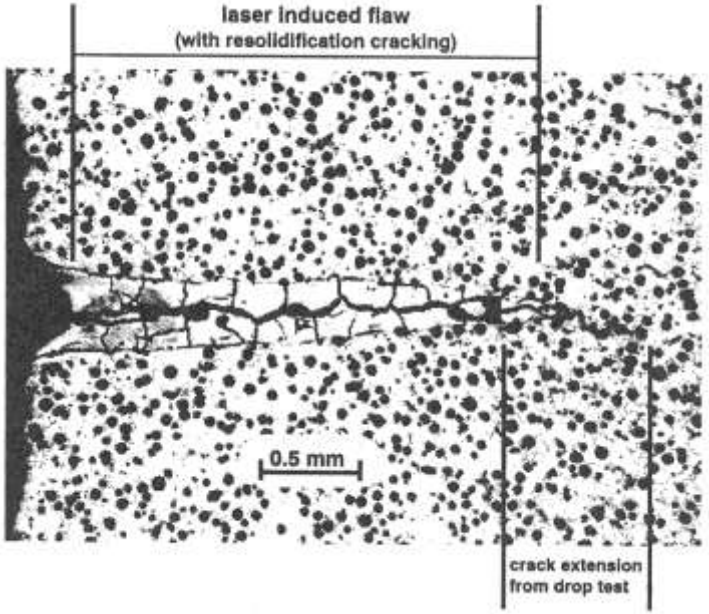
BAM drop test with a thick-walled pipe of ductile cast iron

- corresponding to the 1:2.5 scaled model of a large cylindrical CASTOR V cask
- drop height 9 m
- drop onto steel cylinders located on an unyielding IAEA target
- equipped with an artificial crack-like defect (40 mm in 150 mm wall)

SANDIA National Labs. Drop Tests with MOSAIK Cask



Sequenz von Fallversuchen mit MOSAIK KfK mit künstlichem rissartigem Fehler auf ein Stahlrollenlager auf IAEA-Fundament bei -29 °C



Fehlstelle nach dem 5. Fallversuch:
< 1 mm duktile Rissverlängerung

Versuch 1 bis 4: 9 m Fallhöhe, Risstiefe bis 76 mm (36% Wanddicke) → keine Rissinitiierung

Versuch 5: 18 m Fallhöhe, Risstiefe 57 mm → Risswachstum ohne sprödes Versagen

DOE/BAM Agreement 1998, RadWaste Transport

Signing of the project agreement DOE/BAM
Paris, PATRAM`98

(Bernhard Droste, Kelvin Kelkenberg)

("UMBLELLA" AGREEMENT)

AGREEMENT

BETWEEN THE

DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA

AND

THE FEDERAL MINISTRY OF EDUCATION, SCIENCE, RESEARCH AND TECHNOLOGY OF THE FEDERAL REPUBLIC OF GERMANY

ON

COOPERATION IN ENERGY RESEARCH, SCIENCE AND TECHNOLOGY, AND DEVELOPMENT

(SPECIFIC AGREEMENT for Sandia-BAM-Coop

PROJECT AGREEMENT
BETWEEN
THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA AND
THE FEDERAL INSTITUTE FOR MATERIAL RESEARCH AND TESTING OF THE
FEDERAL REPUBLIC OF GERMANY: TECHNICAL EXCHANGE
AND COOPERATION ON TRANSPORTATION REQUIREMENTS IN THE FIELD OF
MANAGEMENT OF RADIOACTIVE WASTE

WHEREAS:

The Department of Energy of the United States of America and the Federal Institute for Material Research and Testing of the Federal Republic of Germany, hereinafter referred to as the Participants, in furtherance of their countries' mutual interest in increasing the effectiveness of their respective program of energy research, science and technology, and development and technical demonstration in the field of management of radioactive waste:

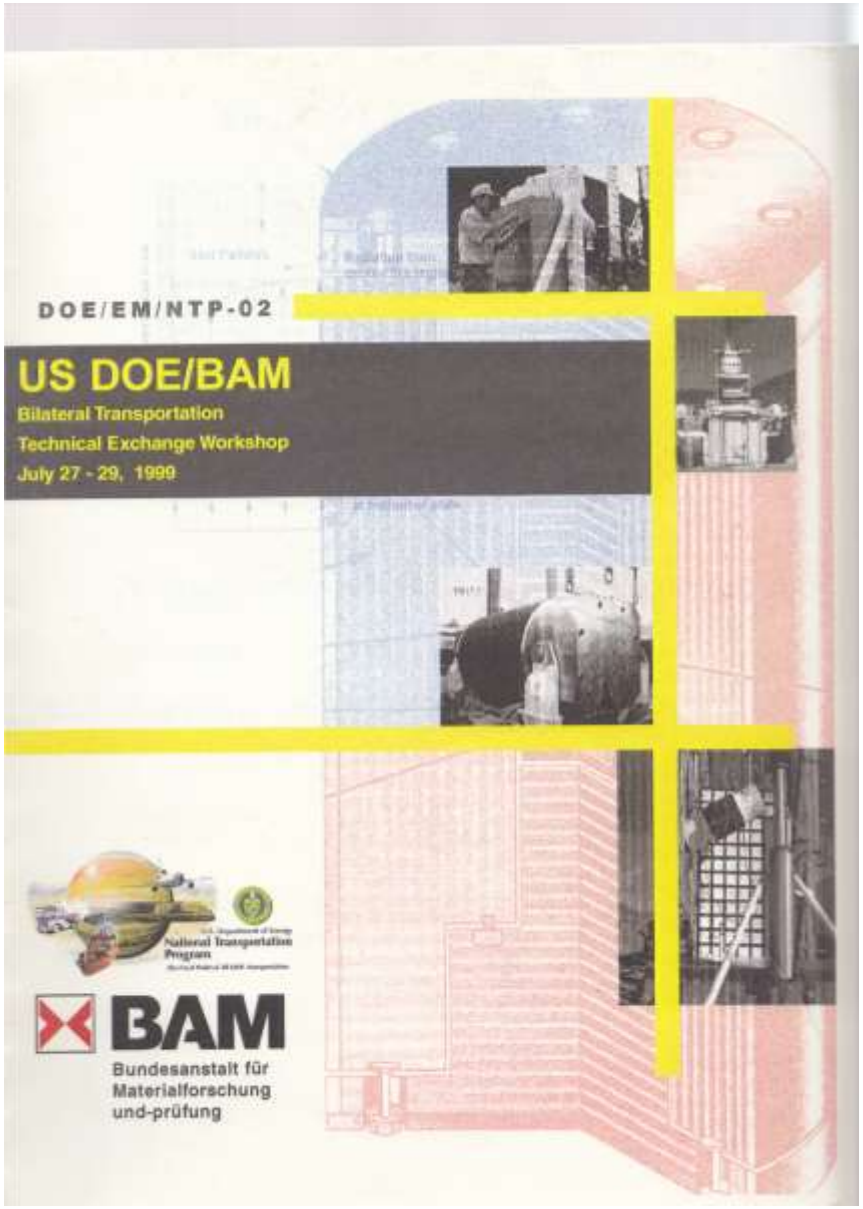
In pursuing related cooperation under the terms of the Agreement on Cooperation in Energy Research, Science and Technology, and Development between the Department of Energy of the United States of America and the Federal Ministry for Education, Science, Research and Technology of the Federal Republic of Germany, hereinafter referred to as the Agreement, on February 20, 1998; and

The Participants wish to cooperate on transportation requirements in the field of management of radioactive waste within the framework established by the Agreement:

The Participants hereby agree as follows:

ARTICLE I
OBJECTIVES

The objective of this Project Agreement is to establish a framework for cooperation and technical assistance related to activities on transportation requirements in the field of management of radioactive waste. Activities carried out under this Project Agreement are subject to, and shall be consistent with, the Agreement.



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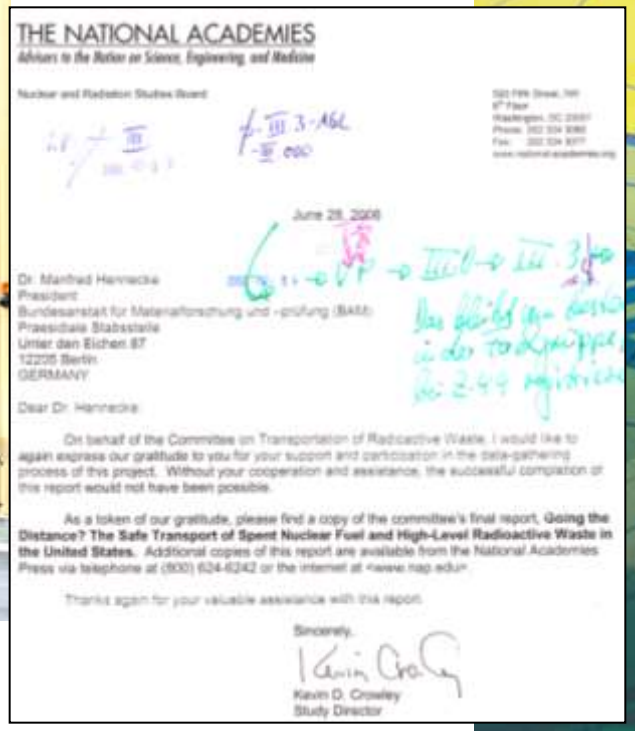
DOE/BAM/SNL Workshop, Albuquerque, 1999

Technical tour to WIPP, Carlsbad

…in front of the first badges of TRU waste inside the repository

(Florentin Lange/GRS, Mona Williams/DOE, Bernhard Droste/BAM, Ashok Kapoor/DOE, Richard Yoshimura/SNL, Uwe Zencker/BAM)

Visit of US National Academies WG
for Spent Fuel Cask Full-Scale Drop Testing
BAM TTS, September 24, 2004
(Technical Tour 2, PATRAM 2004)



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Nuclear and Radiation Studies Board

June 28, 2006

Dr. Manfred Hennecke
President
Bundesanstalt für Materialforschung und -prüfung (BAM)
Praesidiale Stabsstelle
Unter den Eichen 87
12205 Berlin
GERMANY

Dear Dr. Hennecke:

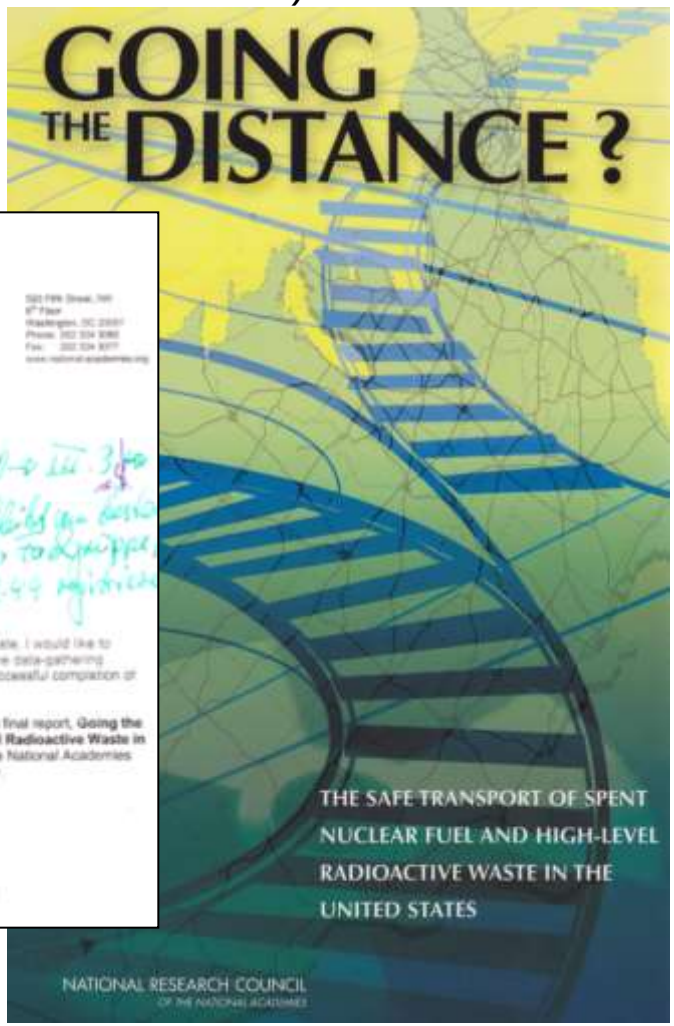
On behalf of the Committee on Transportation of Radioactive Waste, I would like to again express our gratitude to you for your support and participation in the data-gathering process of this project. Without your cooperation and assistance, the successful completion of this report would not have been possible.

As a token of our gratitude, please find a copy of the committee's final report, **Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States.** Additional copies of this report are available from the National Academies Press via telephone at (800) 624-6242 or the internet at <www.nap.edu>

Thanks again for your valuable assistance with this report.

Sincerely,

Kevin D. Crowley
Study Director



Full-Scale Model MSF 69 BG (MHI)

- Total Mass: 127,000 kg
- Length with Impact Limiters: 6,800 mm
- External Diameter of Impact Limiters: 3,100 mm

BAM/US NRC Cooperation 2006-2010

Cooperative Agreement BAM/U.S. Nuclear Regulatory Commission

US NRC Poster PATRAM 2010, London, on comparison of NRC calculations with BAM measurements of a 9-m drop test with the CONSTOR V/TC full scale cask (GNS)

BAM`s intention was also to come to closer cooperation with Sandia NL in the proposed Package Performance Study (PPS)….which was cancelled later on.

Dr. Bernhard Droste

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Finite Element Simulation of a Full-Scale 9-Meter Free Drop Test of a Spent Nuclear Fuel Transportation Cask

Jose A. Pires and Daniel T. Huang, U.S. Nuclear Regulatory Commission

Introduction

This paper presents results of a finite element simulation of a 9-meter, free, side drop test of a prototype CONSTOR® V/TC spent nuclear fuel transportation (SNFT) cask. The 181 tons prototype test specimen was manufactured by the Gesellschaft für Nuklear-Service mbH (GNS) of Germany and was tested by Germany's Federal Institute for Materials Research and Testing (BAM) in 2004 (References 1 and 2). The analyses reported here were conducted by staff of the U.S. Nuclear Regulatory Commission (NRC) under a cooperative research agreement between the NRC and BAM.

The drop test was analyzed using the commercial, dynamic nonlinear, explicit finite element code LS-DYNA. Results from this study can be useful to reaffirm the staff and industry practices for the design and review of SNFT casks.

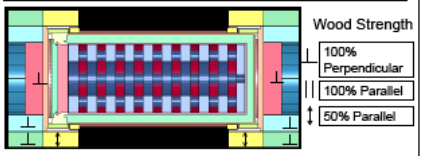
Test Results

Reference 2 provides a description of the data recorded during the test which includes accelerometer data and strain gage data. Analysis of recorded acceleration data indicates that the cask tilted during the drop to an inclination of about 0.36-degrees from the horizontal and that the lid side hit the impact target first [2].

Modeling

- Half of the cask was modeled to take advantage of symmetry
- Number of deformable elements about 530000
- Solid 8-noded elements and Belytschko-Tsai shell elements
- Contact surfaces for the baseline analysis assumed frictionless
- Dynamic wood properties modeled using LS-DYNA honeycomb material model with confined wood properties assumed for the baseline analysis
- Wood properties are direction dependent and depend on confinement
- Honeycomb model does not model effects of varying confining stresses on the behavior of the wood under compression
- Wood in an impact limiter compartment modeled as a single block but contact between wood and steel plates modeled explicitly

Cross-section of finite element model of tested SNFT prototype



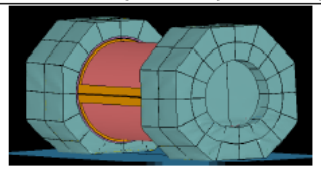
Analysis

- Bolt preload was applied using dynamic relaxation together with the initial stress solid option of LS-DYNA to calculate initial stresses on the bolts, lid, flange and metal O-rings.
- O-rings modeled using nonlinear spring elements with compression only and a compression offset.
- The second step of the analysis consisted of the dynamic impact with an initial velocity perpendicular to the target surface and a cask inclination of 0.46-degrees.

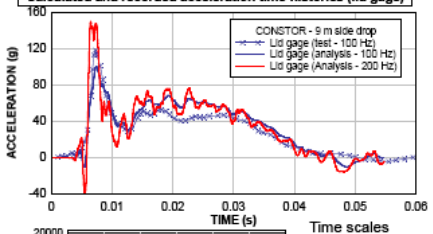
Analysis Results

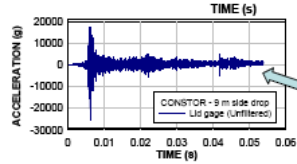
Buckling of the deformed shape of the cask following impact resembles that observed in the test. Significant results from the analysis include the rigid body accelerations, which represent global forces on the cask. Of most interest, however, are accelerations at specific locations (gages), strains and O-ring forces.

Calculated deformed shape of the test specimen after impact



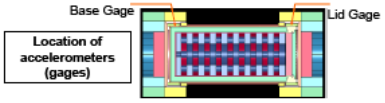
Calculated and recorded acceleration time-histories (lid gage)





Time scales shifted to match starting time.

Unfiltered (analysis)

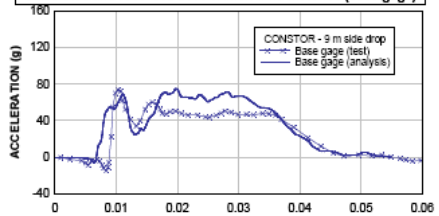


Location of accelerometers (gages)

Local Acceleration Histories

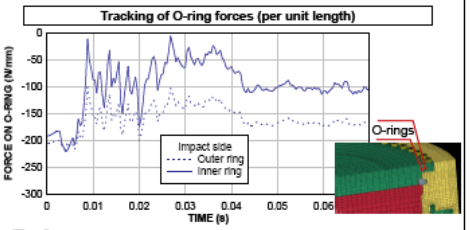
- Calculated filtered acceleration time-histories compare well with the recorded acceleration time-histories filtered in the same manner.
- Average calculated accelerations (filtered) are somewhat higher than the average values from the recorded (filtered) data.

Calculated and recorded acceleration time-histories (base gage)



- 100 Hz low pass filter.
- Time scales shifted to match starting time.

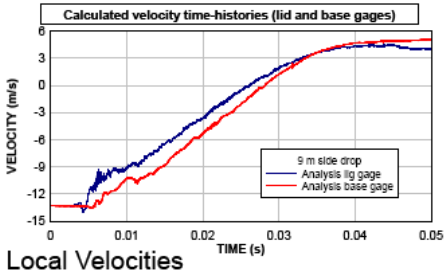
Tracking of O-ring forces (per unit length)



References

1. Konig, S. R., et al. (2005), "Full-Scale Drop Test of the CONTO R® V/TC Package Program, and Preliminary Results," J. Nuclear Materials Management, XXXIII (3), pp. 4-10.
2. Musolf, A.K. et al., (2007), "Drop Test Results of the Full-Scale CONSTOR® V/TC Prototype," PATRAM 2007, Miami, Florida, USA, 2007.

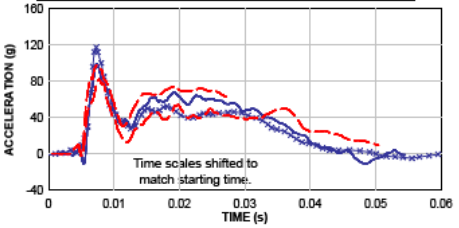
Calculated velocity time-histories (lid and base gages)



Local Velocities

- Calculated velocity time-histories compare well with time-histories derived from measured and filtered acceleration data reported in Reference 2
- Calculated velocities change sign earlier than those from the test (as a consequence of higher calculated average accelerations)

Calculated acceleration histories (lid gage) for different friction conditions and material properties



Limited Sensitivity/Parametric Study

- Baseline case: frictionless contact and confined wood dynamic properties
- Case 1: frictional contact and unconfined wood properties
- Case 2: frictional contact and confined wood properties
- Frictional contact increases the accelerations (greater effect appears to be from the contact between the impact limiters and target)
- Unconfined properties soften the impact and decrease the accelerations

Strains

- Calculated strains did not compare as well with the recorded strains
- Study continuing to determine modeling details that affect the calculation of the strains and caused the deviations

Conclusions

- Analysis of full-scale test data proving useful for benchmarking
- Benchmarking needs to include unique features of specimens and tests that affect measurements
- Analysis can provide useful results and insights provided that dynamic material properties for impact limiters' materials are available
- Analysts should perform sensitivity or parametric studies to account for:
  - Uncertainties on material properties
  - Approximations on material models under impulsive loads and time-varying multi-axial states of stress
  - Uncertainties on friction between contact surfaces

Acknowledgments

These analyses were conducted under and international cooperative agreement between the NRC and Germany's BAM who separately conducted the test and subsequently shared the test data with the NRC.

Disclaimer Notice

BAM/US NRC Cooperation

Visit of US NRC Commissioner Ms K.L.Svinicki in Berlin and at BAM Test Site, March 24, 2010

Conclusions, Recommendation:

Proceed with Cooperation!!!!